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Supplementary Information

Highly flexible and semi-transparent Ag-Cu alloy electrodes for high performance flexible thin film heaters

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***Fabrication of TFHs with an Ag-Cu alloy film**:* To demonstrate the feasibility of the Ag-Cu alloy films as a semi-transparent electrode for TFHs, conventional film heaters (25 × 25 mm^2) with two-terminal side contact were fabricated on the Ag-Cu alloy electrode as shown in **Figure S1**. After wet cleaning of the Ag-Cu film, a 200 nm-thick Ag side-contact electrode was sputtered onto the Ag-Cu alloy film. The DC voltage was supplied to the Ag-Cu alloy-based TFHs by a power supply (OPS 3010, ODA technologies) through an Ag contact electrode at the film edge. The temperature of the TFHs was measured using a thermocouple mounded on the surface of the TFHs and IR thermal imager (A35sc, FLIR). For the defrost test, the Ag-Cu alloy film was placed in a refrigerator for 60 min to form frost on the surface.

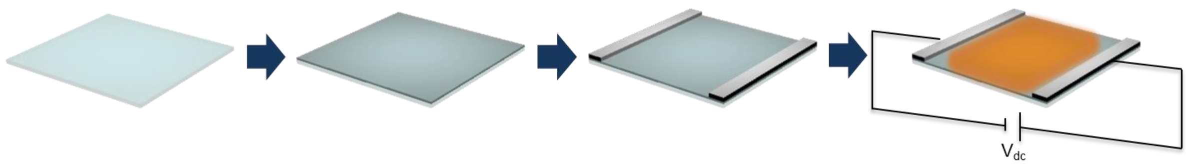

Figure S1. Schematic of the TFH fabrication process using thermal evaporated the Ag-Cu alloy film. Two terminal side Ag contact electrodes were fabricated on the Ag-Cu alloy films.

Figure S2 shows surface FESEM images of 14-nm-thick Ag-Cu alloy film before and after outer/inner bending, dynamic fatigue, and twisting tests. Even after 1 mm outer/inner bending of the samples, the surface of the Ag-Cu alloy was similar to that of the as-deposited Ag-Cu alloy film, confirming the good flexibility of the Ag-Cu alloy film. FESEM images of the surface before and after 1 mm outer/inner bending revealed a smooth morphology without surface defects, such as cracks or delamination, as shown in **Figure S2**b. In addition, the Ag-Cu alloy film showed a similar surface FESEM image to the as-deposited sample even after 10,000 dynamic outer/inner bending cycles (**Figure S2**c). The Ag-Cu alloy film showed no changes in surface morphology after the twisting test, as shown in **Figure S2**d.

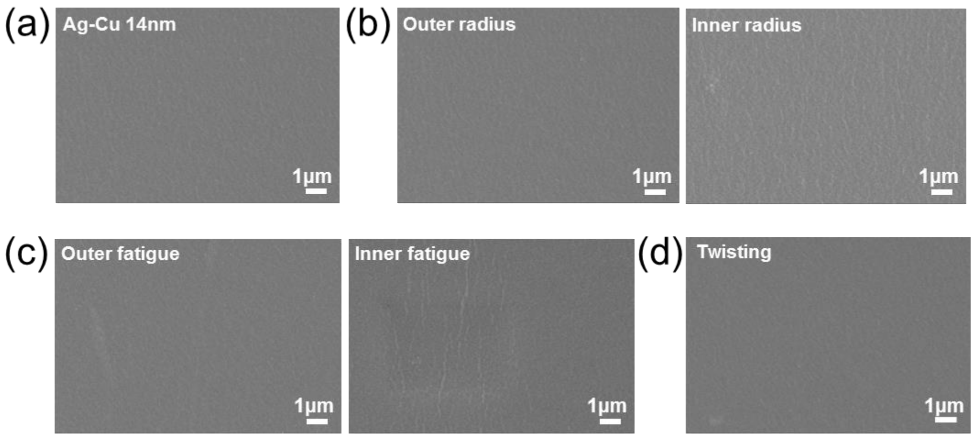

Figure S2. Surface FESEM images of (a) as-deposited Ag-Cu alloy film after (b) 1 mm outer/inner bending test, (c) 10,000 dynamic fatigue tests, and (d) 15° twisting tests.

Figure S3 shows the temperature profiles of the Ag-Cu alloy film-based TFHs after 10,000 cycles dynamic outer/inner bending fatigue tests and 5,000 cycles dynamic twisting test. As can be expected from **Figure S2**, The Ag-Cu alloy films based TFHs showed an identical temperature profiles and easily reached at a saturation temperature of 100 °C when DC voltage of 4V was applied.

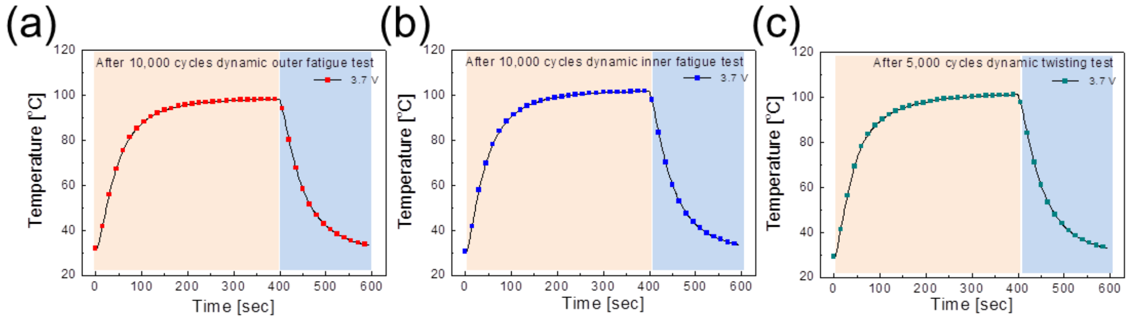

Figure S3. Temperature profiles of the Ag-Cu alloy based TFHs after (a) dynamic outer and (b) inner bending fatigue tests and (c) dynamic twisting test.